SPECIFICATION

GAS ENGINE ELECTRIC POWER GENERATING SYSTEM EFFECTIVELY UTILIZING GREENHOUSE GAS EMISSION CREDIT

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a gas engine electric power generating system. The system effectively utilizes coal mine methane gas which is low in methane concentration and large in its variation by the gas engine electric power generating system. Using coal mine methane gas also facilitates advancing economic development in developing countries by enabling these countries to profit from coal mine methane gas based electric power generation and also GHG(greenhouse gas) emission dealing.

Description of the Related Art

In growing awareness of a worldwide environmental problem, country-by-country objectives regarding reduction of carbon dioxide emissions were decided at the 3rd Conference of the Parties to the United Nations Framework Convention on Climate Change held in 1997 in Kyoto. In the meeting, a Kyoto mechanism was established for the reduction of GHG (CO_2, CH_4, N_2O, etc.) emissions in accordance with the conditions of countries and for the promotion of the efficiency of reduction.

The Kyoto mechanism is a system to promote worldwide cooperation and emission credit dealing for the reduction of GHG. A concept of carbon dioxide emission credit (right

to emit a certain amount of carbon dioxide) was introduced and which aims to utilize market principles as a supplementary scheme for achieving the reduction objective of each country. When each entity (nations, enterprises, stores, families, etc.) takesaction of directly exhausting GHG (for example, consuming energy for operating machines, consuming gasoline for running vehicles, etc.) or when it takes action of indirectly exhausting GHG (for example, mining of coal, selling of gasoline, etc.), it is assumed that each entity is under an obligation to bear carbon dioxide emission credit corresponding to the exhausted amount of GHG.

As for energy, coal industries of major coal yielding nations of the world(China, CIS, Europe, and the United States, etc.) are expected to play an important roll as energy suppliers even in the middle part of this century.

However, in proportion to the coal production, methane gas of 10~40Nm^3(in terms of pure methane) per ton of coal is released to the atmosphere as recovered methane gas(30~50% concentration, air diluted) and ventilated methane gas(0.3~0.7% concentration, air diluted). Therefore, technology and business to effectively utilize the methane gas now being released to the atmosphere are very prospective and will make large social and economic contributions.

For example, the amount of coal mine methane gas released by countries & districts is; China 14,400(206), CIS 4,200(60), and other developing countries 3500(50) totaling to 22,100(316), which is over twice the total 11,000(157) of developed countries. (Units are in million m^3/year, numbers in parentheses are the values converted to carbon

dioxide in million tons/year). Utilizing the mine methane gas of developing countries is very advantageous for emission credit trading.

There are two kinds of coal mine methane gas as shown in Figure 5. One is recovered methane gas recovered by a vacuum pump from bore holes for degassing for safety, and the other is ventilated methane gas exhausted together with the ventilation air from mine shafts and coal seams. The concentration of methane in these gases is low. For example, that of the former is 30~50% and that of the latter is extremely low at 0.3~0.7%.

To use a boiler or gas turbine as a heat engine to utilize methane gas has been considered.

However, if recovered methane gas having a methane concentration of 30~50% is to be used for a gas turbine or boiler, as combustion temperature is low and methane concentration varies from time to time, it is not practical. It is difficult to use even the recovered methane gas for a gas turbine. Actually, the usage of recovered methane gas has been limited to use as a fuel by nearby households, or in the case of a boiler used only as auxiliary fuel.

Therefore, regarding the utilization of coal mine methane gas, even recovered methane gas is seldom utilized, and almost all of the coal mine methane gas is released to the atmosphere.

However, the greenhouse effect index (here and hereafter, this term is identical to "global warning potential") of methane gas is 21 times that for methane gas that is burnt and released to the atmosphere as CO_2. For example, coal mine methane gas release in China is 14.4 billion m^3, which is

equivalent to more than 10% of total amount of CO_2 release in Japan.

Therefore, if Japan establishes an enterprise to effectively consume the coal mine methane gas in China to change the methane gas to CO_2 and release to the atmosphere as CO_2, a reduction of greenhouse effect index can be achieved. More specifically, a green house effect index of 20 may be realized by burning the methane gas and then releasing the combusted gas to the atmosphere, versus releasing the methane gas directly to the atmosphere. A greenhouse effect index of 20 is realized because burning methane yields a greenhouse effect index for Co_2 of 1 and directly releasing methane gas to the atmosphere yields a greenhouse effect index of 21. Thus, taking the difference between these greenhouse effect indices, i.e. 21-1, yields a reduction of greenhouse effect index equal to 20. This reduction of greenhouse effect index can be traded as an emission credit.

For example, if developing countries such as China, CIS, etc. start business to effectively consume coal mine methane gas through receiving finance or loan aid from the Asian Development Bank, the World Bank, or ODA of Japan, etc., the enterprising body can make profits from the enterprise and also can make profits by selling CO_2 emission credit to a surcharge payment obligator. This surcharge system is a system that a country(government) for example levies a toll on each enterprise for its releasing of carbon dioxide. There are two methods, one is that the surcharge is added to fuel price, the surcharge being proportional to the amount of carbon dioxide emission calculated from the amount of primary energy, and the other is that the surcharge is levied

at the time carbon dioxide is actually released.

SUMMARY OF THE INVENTION

The present invention is made to solve the problem mentioned above, and an object is to provide an art on the basis of which can be established an enterprise which effectively utilizes coal mine methane gas having a low concentration of methane and large in its variation and which serves to smoothly advance the economic development in developing countries by mortgaging GHG emission credit for financing or loan aid utilizing CO_2 emission credit trade system.

Another object of the present invention is to achieve the above-mentioned object by effectively utilizing the gas engine equipped with a combustion diagnosis apparatus that the present applicant developed(see WO02/079629).

First, the structure of the principal part of the gas engine used for the present invention will be explained with reference to Figure 1. In Figure 1, the reference numeral 20 is the main body of a gas engine. A pilot fuel ignition device 11 comprising an injection nozzle 11b and a sub-chamber 11c is mounted in the upper part of the combustion chamber 44 formed by a cylinder and piston, flame jet 44a being injected from said sub-chamber 11c into the combustion chamber 44, recovered methane gas and ventilated methane gas being mixed in the inlet pipe 9 before entering into the combustion chamber 44. Reference numeral 41 is the inlet valve.

As the gas engine used in the present invention is a pilot ignition engine and the ignition of the gas fuel in the

combustion chamber 44 occurs through the flame jet 44a injected from the sub-chamber 11c, very lean mixture of methane of 10% or lower, preferably 3~5%, or 3~4% can be ignited. Therefore, recovered methane gas of methane concentration of 30~50% and ventilated methane gas of methane concentration of 0.3~0.7% are mixed in the inlet pipe before entering into the combustion chamber 44 to be reduced to lean mixture of 4~5% methane by means of a combustion control apparatus 200.

In this case, it is preferable to control so that excess air ratio is approximately 2.

With the gas engine, very lean mixture of methane can be ignited and engine performance can be improved.

To cope with the combustion of very lean methane mixture and from time to time changing methane concentration, the gas engine is equipped with a combustion diagnosis apparatus 100, by virtue of which misfire and knocking can be evaded.

In this way, the operation method of a gas engine can be established, by which coal mine methane gas that changes from time to time in methane concentration can be effectively utilized by proper combination of recovered methane gas and ventilated methane gas.

By connecting an electric power generator to the gas engine, profit form electric power production can be made.

The exhaust gas of the gas engine can be utilized for producing steam and then released to the atmosphere. Thus, coal mine methane gas is changed to carbon dioxide by the combustion in the gas engine and released to the atmosphere, so that reduction of greenhouse effect index of 20 can be achieved in comparison to releasing methane gas to the

atmosphere. This is because releasing methane gas to the atmosphere has a greenhouse effect index of 21, whereas the greenhouse effect index of CO_2 is 1. This reduction of greenhouse effect index can be traded as an emission credit.

The enterprising body planning to establish the gas engine electric power generating system near a coal mine can secure financing if carbon dioxide emission credits are mortgaged during the application for financing or loan aid to the Asian Development Bank or ODA of Japan, etc. It should be understood that financing may be made under the condition that the enterprising body establishes the gas engine electric power generating plant at a coal mine, for example, in a developing country.

The enterprising body reports to the U.N. or the Japanese Government, etc. the CO_2 emission reductions to be achieved by the difference 20 of greenhouse effect index of methane and CO_2. The enterprising body and can register this carbon dioxide emission credit on the emission credit market to prepare for trading with credit surcharge payment obligators. The purchaser of CO_2 emission credits may be other than the Japanese Government.

After securing financing from the Asian Development Bank, etc., the enterprising body purchases the principal parts and assembles the gas engine electric power generating system.

The enterprising body can get not only profit through selling the electric power produced by the operation of the gas engine electric power generating system, but also through the reduction of 20 times the greenhouse effect index of carbon dioxide. With the profit obtained by selling the

carbon dioxide emission credit to surcharge payment obligators on the market, the loan can be paid-off in a short period. As a result, the enterprising body can get profit dually and promote economic development in developing countries by effectively utilizing CO_2 emission credits, i.e. mortgaging CO_2 emission credit for securing financing or loan aid. There may be the case that CO_2 emission credit is not necessary as a mortgage for securing financing or loan aid for the project of establishing the gas engine electric power generating plant, for there may be a fund that invests on the basis of prospective investment return.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic cross-sectional view of the structure of the principal part of the gas engine for utilizing coal mine methane gas in the system according to the present invention.

Figure 2 is a diagrammatic representation showing the total configuration of the gas engine for utilizing coal mine methane gas in the system according to the present invention.

Figure 3 is an example of control flowchart of said gas engine.

Figure 4 is a diagram showing the relation of cylinder pressure to crank angle of said gas engine.

Figure 5 is a conceptual rendering showing a combination of a coal mine methane gas and the system according to the present invention.

Figure 6 is a conceptual rendering showing a business model of carbon dioxide credit trade.

Figure 7 is a table showing the electric power production

and carbon dioxide reduction by region when utilizing the business model of Figure 6.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will now be detailed with reference to the accompanying drawings. It is intended, however, that unless particularly specified, dimensions, materials, relative positions and so forth of the constituent parts in the embodiments shall be interpreted as illustrative only not as limitative of the scope of the present invention.

Figure 2 shows the total configuration of the gas engine. Reference number 20 is the main body of a gas engine, 45 is a piston, 46 is a crankshaft, 44 is a combustion chamber, 41 is an inlet valve, 42 is an exhaust valve, and 43 is an exhaust pipe.

Reference number 9 is an inlet pipe. A recovered methane gas injection device 10 is provided midway along inlet pipe 9 for injecting recovered methane gas into the ventilated methane gas flowing in inlet pipe 9.

Reference number 8 is a gas supply pipe for connecting a recovered methane gas tank (not shown) accommodating recovered methane gas and sgas injection device 10. Reference number 7 is a gas supply electromagnetic valve provided at the entrance of gas supply pipe 8 to enter into gas injection device 10. A combustion control device 200, which is detailed later, receives the signal of detected methane concentration from a recovered methane gas concentration detector, and electromagnetic valve 7 is controlled under the control signal from combustion control

device 200 to be shut-off or adjusted.

Reference number 11 is an ignition device for torch-igniting the pilot fuel oil injected into a sub-chamber(see Figure 1) from a pilot fuel injection valve 0011 to promote the combustion of lean methane gas/air mixture in the main combustion chamber.

The gas pressure in the combustion chamber, i.e. cylinder pressure is detected with a cylinder pressure detector 1, and crank angle is detected with a crank angle detector 2.

Reference number 100 is a combustion diagnosis apparatus composed of a noise filter 3, an amplifier 4 for amplifying the cylinder pressure signal passed through the noise filter, and a combustion diagnosis section 5. The noise filter 3 and amplifier 4 are not necessarily required for constituting the system.

Noise filter 3 is composed of a low-pass filter for filtering out the noise on the signal inputted from cylinder pressure detector 1. Combustion diagnosis section 5 diagnoses the combustion condition in combustion chamber 44 on the basis of the cylinder pressure signal amplified by amplifier 4 with the assistance of the crank angle signal from crank angle detector 2.

The combustion control device 200 receives the signal of the result of diagnosis at combustion diagnosis section 5, and shuts off or controls the opening of gas supply electromagnetic valve 7 and also controls the action of ignition device 11 based on the diagnosis result signal. The result of diagnosis by combustion diagnosis section 5 is displayed on a displaying apparatus 6.

During operation of the methane gas engine of this

configuration, when pilot fuel is allowed to ignite in ignition device 11 and a gas valve(not shown) is opened, recovered methane gas from a recovered methane gas tank(not shown) is supplied to gas injection device 10, such that the recovered methane gas is adjusted in pressure by a gas pressure adjusting device(not shown). By opening gas supply electromagnetic valve 7, the recovered methane gas is injected into ventilated methane gas flowing through gas injection device 10 provided midway along inlet pipe 9 to be mixed with the flowing ventilated methane gas. (The ventilated methane gas may be mixed with air as necessary.) The mixture is introduced into the combustion chamber 44 through the inlet valve 41 and ignited by the flame jet 44a (see FIG.1) spouting from ignition device 11 to be burned in the combustion chamber 44.

The working of the combustion diagnosis apparatus will be explained below.

The gas pressure in the combustion chamber 44 detected by cylinder pressure detector 1 is inputted to noise filter 3. Noise filter 3 is composed of a super low-pass filter in the combustion diagnosis apparatus 100, such that high frequency noises are filtered. The cylinder pressure signal smoothed through the filtration is amplified by amplifier 4 to be inputted to combustion diagnosis section 5.

The crank angle signal from crank angle detector 2 is also entered into combustion diagnosis section 5.

Next, an example of combustion diagnosis operation by combustion diagnosis apparatus 100 will be explained with reference to the combustion control flowchart shown in Figure 3 and cylinder pressure curve shown in Figure 4.

The cylinder pressure-crank angle curve, as shown in Figure 4, is obtained in combustion diagnosis section 5 from the cylinder pressure inputted from cylinder pressure detector 1 and the crank angle inputted from crank angle detector 2. It should be understood that curve A is a cylinder pressure curve representing normal combustion.

Referencing Figure 3, initially compression pressure P_0 at a predetermined crank angle in the compression stroke, shown in Figure 4, is compared E1 in a compression pressure judging means(step) with a predetermined permissible compression pressure P_{c0}. P_{c0} is the minimum permissible pressure in the compression stroke. The compression pressure judging means determines whether the compression pressure P_0 is abnormally low compared to the normal value. Compression pressure P_0 may be abnormally low due to troubles such as gas leakage or mechanical troubles and is considered abnormally low when it is equal to or lower than the permissible compression pressure P_{c0}, i.e. when $P_0 \leqq P_{c0}$. Curve E, shown in Figure 4 is a cylinder pressure curve when the compression pressure is abnormally low.

Next, as shown in Figure 3, the ratio of the maximum cylinder pressure P_p to compression pressure P_0 at a predetermined crank angle in the compression stroke P_p/P_0 is calculated. The calculated maximum pressure ratio P_p/P_0 is compared in a maximum cylinder pressure judging means(step) with a predetermined permissible maximum pressure ratio P_{p0}. It should be understood that P_{p0} is the maximum permissible pressure ratio. The maximum cylinder pressure P_p ,sometimes is considered abnormally high

compared to the design value(normal value) when the calculated maximum pressure ratio P_p/P_0 is determined E2 to be equal to or greater than permissible maximum pressure ratio P_{p0}, i.e. when $P_p/P_0 \geqq P_{p0}$. Additionally, the maximum cylinder pressure P_p may be considered abnormally high when the number of operation cycles N_h in which the maximum pressure ratio P_p/P_0 is determined E3 to be equal to or greater than a predetermined pressure ratio P_{h1}, i.e. when $P_p/P_0 \geqq P_{h1}$, is determined E4 equal to or greater than a permissible number N_{h0}, i.e. when $N_h \geqq N_{h0}$.

When the maximum cylinder pressure P_p is determined to be normal, a knock judging means(step) determines E5 whether a knock is occurring in combustion chamber 44. Specifically, the knock judging means determines E6 whether the number of cycles S_n in which maximum pressure ratio P_p/P_0 is equal to or greater than a predetermined permissible pressure ratio of knock P_{h2}, i.e. when $P_p/P_0 \geqq P_{h2}$, is equal to or greater than a permissible number of cycles S_{n0}, i.e. when $S_n \geqq S_{n0}$. Curve B, as shown in Figure 4, is a cylinder pressure curve when knock has occurred. When it has been determined that knock is occurring, gas supply valve 7 is adjusted to decrease the supply of recovered methane gas.

When it has been determined that knock is not occurring, a misfire judging means(step) determines E7 whether the maximum pressure ratio P_p/P_0 is equal to or less than a predetermined minimum permissible pressure ratio P_n, i.e. when $P_p/P_0 \leqq P_n$. The misfire judging means also determines E8 whether the combustion pressure ratio P_1/P_0 is equal to or less than the predetermined permissible pressure ratio P_m of misfire, i.e. when $P_1/P_0 \leqq P_m$. When the misfire judging

means determines that $P_p/P_0 \leqq P_m$ and that $P_1/P_0 \leqq P_m$ misfire is occurring. When misfire occurs, gas supply valve 7 is adjusted to increase the supply of recovered methane gas. It should be understood that the combustion pressure ratio P_1/P_0 is the ratio of a pressure P_1 at a predetermined crank angle in the combustion stroke to the pressure P_0 at a predetermined crank angle in the compression stroke as shown in Figure 4.

A predetermined crank angle θ_1 in the combustion stroke, corresponding to where pressure P_1 is detected, is determined to be at a position of crank angle symmetric with a position of a predetermined crank angle $-\theta_1$ in the compression stroke, corresponding to where pressure P_0 is detected, and about a top dead center, as shown in FIG.4.

Thus, more accurate combustion control can be achieved by using pressure ratios, instead of pressure itself, such that combustion conditions are determined and controlled.

The electric generating system adopting a methane gas engine E is explained with reference to Figure 5. Gas engine E is installed near a coal mine and recovered methane gas is supplied as fuel to the gas engine through piping.

More specifically, ventilated methane gas exhausted from the mine cavity and the coal face, together with ventilation air, is introduced to the inlet pipe of engine E.

Gas engine E can be connected with an electric generator G, and exhaust gas of gas engine E can be introduced to a boiler B to produce steam that is used for powering utility equipment on the mine premises. The electric power generated by generator G is used for powering utility equipment on the mine premises by way of a transformer

facility and surplus electric power is supplied through power lines and sold to users as commercial electric power.

The exhaust gas from boiler B is released to the atmosphere. However, in this case, carbon dioxide produced by the combustion of coal mine methane gas is released as the exhaust gas. As the greenhouse effect index of methane is 21 and that of CO_2 is 1, the reduction of 20 times the greenhouse effect index of carbon dioxide is achieved. This reduction of greenhouse effect index can be traded as carbon dioxide emission credit.

A business model of the gas engine electric generating system is explained with reference to Figure 6. The business model is for establishing a gas engine electric generating system in a coal mine in China, for example.

Enterprising bodies of the gas engine electric power generating system could be government-owned enterprises, mine owner companies, owners of steel, chemistry, electric power related enterprises, engineering companies and the like. The enterprising bodies may be institutions specifically established for constructing the electric power generation system.

The enterprising body applies to the World Bank or ODA of Japan, etc. for financing or loan aid, and at the same time applies for credit approval on the condition that that it establishes the gas engine electric power generating system in a coal mine in China. Approval is to be awarded by a CDM Committee or the Committee of Article 6. The endorsement by the host country and acknowledgement by the investing country are necessary. It should be understood that the investing country could be other than Japan. Upon

applying, if carbon dioxide emission credit is offered as security, the enterprising body can get funding easier.

The enterprising body reports to the U.N. or the Japanese Government of the reduction of greenhouse effect index and registers this carbon dioxide emission credit on the emission credit market to prepare for trading with credit surcharge payment obligators.

After getting financing from the Asian Development Bank, etc., the enterprising body purchases the principal parts and assembles the gas engine electric power generating system.

The enterprising body can get not only profit through selling the electricity produced by the operation of the gas engine electric power generating system, but also can achieve the reduction of 20 times the greenhouse effect index of carbon dioxide. With the profit obtained from selling the carbon dioxide emission credit to credit surcharge payment obligators on the market, the loan can be paid off in a short period. Thus, the enterprising body can get profit dually.

The table of FIG.7 shows a worldwide spreading effect of the implementation of the present invention. In the left column of the table, regional total amounts of coal mine methane gas emissions in the world are shown.

If it is assumed that each country utilizes one third of recovered methane gas for the gas engine electric power generation system, generation capacity is 5180 MW and production of electric power is 45 billion kWh/year. This corresponds to the production of 50~100 large nuclear power plants. A reduction of 20 million ton/year of CO_2 can be

achieved, which corresponds to 20% of the total annual amount of CO_2 emissions of Japan.